# ECONOMICS OF BIOFUELS

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## 1. SUMMARY

Biofuels include a wide variety of energy products, ranging from waste wood through to synthetic fuels such as ethanol, vegetable oil methyl esters, and methanol. With the growing interest in and concern about global climate change, a number of world and national studies of methods to reduce the increase in greenhouse gases (GHGs) have placed surprisingly high emphasis on the production of biofuels, coupled with improvements in energy efficiency of all energy activities (e.g., Reddy et al., 1997). This would require a major expansion in the production of biomass feedstocks worldwide, with significant effects on agriculture, agroforestry and forestry.

The present paper discusses briefly a number of issues for Canadian agriculture. These include the amount of biofuels produced from agricultural feedstocks, and likely near-future production, comparisons with the total amount of bioenergy used in the Canadian economy, comparisons with agricultural fuel requirements, the GHG emissions from biofuels, including emissions from feedstock production, present economics, methods to reduce biofuel costs, present tax incentives and related benefits, future technology and the outlook for reductions in costs and GHG emissions.

## 2. BIOFUELS IN THE CANADIAN ECONOMY

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Canadian energy use in 1990 was 12.08 EJ, composed of 3.46 exajoules (EJ, $10^{18}$ joules) oil, 2.75 EJ natural gas, 1.32 EJ coal, 0.93 EJ net nuclear, 3.12 EJ net hydro and an estimated 0.5 EJ biofuels (Klass, 1998). Most of the biomass used in the Canadian economy comes from the forestry sector. About 41.7 million tonnes (t) of biomass were used in the form of pulping liquors, wood chips and bark, and fuel wood, including wood wastes (Jaques, 1992). In addition, 5 million t of wood waste were incinerated. Some of this material might be converted in the future to synthetic fuels, such as ethanol (U.B.C., 1998). For comparison, Canada's total production of the ten major crops (grains, hay, oilseeds) was about 87 million t in 1997 (Statistics Canada Catalogue 22-002).

## 2.1. Biofuel ethanol produced from agricultural materials: significance for agriculture and for Canadian gasoline substitution

Until recently, very little biofuel production was based on agricultural materials in Canada. Small amounts of ethanol were produced from grain sources in plants in Manitoba, Saskatchewan and Ontario. This situation is rapidly changing as new plants, some world-scale in size, are recently built, are under construction, or are seriously planned. Table 1 summarizes ethanol production and plans.

If all the plants planned are built, as well as those in production or under construction, the total ethanol production capacity would be 531 to 626 million litres (419,000 to 490,000 t)(12.49 to 14.71 PJ) (petajoules = $10^{15}$ joules). This production would represent about 9 to 10 percent of all agricultural fuel needs in 1997 of 144.79 PJ (made up of 1.29 billion litres of gasoline and 2.66 billion litres of diesel fuel) (Statistics Canada Catalogue 57-003 for 1997). The ethanol production will be blended with gasoline. The total production of ethanol, when in place, would represent, on an energy replacement basis, about 28 to 33 percent of all Canadian agricultural gasoline consumption. The total Canadian gasoline consumption in 1997 was 36.38 billion litres (1,261 PJ). Thus the

potential ethanol production represents about one percent of all gasoline used in Canada. It would provide enough ethanol to make a 10 percent blend for 15 to 17 percent of all Canadian gasoline consumption in 1997.

Table 1. Ethanol production from grain sources in Canada (in production, under construction or planned)

| Location | Production capacity (millions of L) | Status |
|---|---|---|
| Chatham, Ont. | 150 | In production 1997 |
| | 150 | Planned |
| Cornwall, Ont. | 55 (?) | Seeking financing |
| Tiverton, Ont. | 21 | In production |
| Varennes, Que. | 150 | Completing financing |
| Minnedosa, Man. | 12 | In production |
| Lanigan, Sask. | 12 | In production |
| Red Deer, Alta. | 21 | In production 1998 |
| Two Hills, Alta. | 7.5 | Under construction |
| | 7.5 | Planned |
| Alberta site selection | 40 (?) | Feasibility study |
| Total built or building | 223.5 | |
| Total incl. plans | 531 to 626 | |

Source: various issues of the Canadian Report on Fuel Ethanol.

## 3. GREENHOUSE GAS EMISSIONS

### 3.1. Greenhouse emissions from ethanol produced from grain: comparisons with gasoline

A recent study by Argonne National Laboratories in the U.S.A. calculated the total GHG emissions from ethanol produced from corn grain in modern plants in the corn belt of

the U.S.A. (Wang et al., 1997). Wang et al. (1997) calculated that the ethanol component of E85 (85 percent ethanol) reduced GHG emissions by 39.0 percent and the ethanol component of E10 (ten percent ethanol) (the formulation sold widely) reduced GHG emissions by 35.6 percent. Ethanol used in E85 improves fuel efficiency slightly; hence the difference in GHG emission reductions between the two formulations. In a more recent analyses, Wang (1998) calculated that ethanol reduced GHG emissions by about 32 percent, based on slightly different scenarios.

Table 2 illustrates the difference between gasoline and E85 in terms of the relative importance of different GHGs in the total effect. It also highlights the importance of nitrous oxide emissions from the fertilizer nitrogen used to grow the corn in the total GHG emissions attributed to ethanol production. Analyses also found that the assumptions about how energy and GHG emissions are assigned to different products of the plant (ethanol and livestock feed) could have a considerable effect of the GHG emissions assumed associated with ethanol.

Table 2. Sources of GHG emissions ($CO_2$ equiv. gm/mi) in gasoline and E85 (derived from Wang et al., 1997)

| Greenhouse gas | Gasoline | E85 (a) | E85 (b) |
|---|---|---|---|
| Carbon dioxide | 455.4 | 264.3 | 251.3 |
| Methane | 10.5 | 4.2 | 4.9 |
| Nitrous oxide | 3.2 | 56.2 | 57.7 |
| Totals: | gasoline= 469.1; | E85 (a)= 324.7; | E85 (b)= 313.9 |

(a) current mix of coal and natural gas process fuels
(b) all natural gas process fuel (all Canadian plants)

Assumptions about the many variables included in complete fuel-cycle analyses can change results considerably. Some previous analyses cited by Wang et al. (1997) ranged

from ethanol having 25 percent higher GHG emissions than gasoline to ethanol having GHG emissions 40 percent lower than gasoline. The more recent analyses, using more recent data, tend to be similar to Wang et al. (1997).

### 3.2. Greenhouse gas emissions from ethanol produced from lignocellulosic feedstuffs

Lignocellulosic feedstuffs include a variety of waste materials or by-products such as sawdust and waste wood, crop residues, portions of municipal solid waste such as waste paper and tree prunings, and purpose grown crops such as perennial grasses (e.g., switchgrass) and fast growing trees (e.g., willow and poplar). Various processes are under research and development to process such materials into ethanol and co-products.

A detailed review article on the topic has been pubished recently (Lynd, 1996). Processes to convert lignocellulosic materials to ethanol are much less developed than processes to convert starchy materials such as grain into ethanol. Nonetheless, the potential appears to be there to produce ethanol considerably more cheaply than from grain (see section 4), in much larger quantities (avoiding much of the potential conflict between food and fuel), and with lower GHG emissions than ethanol produced from grain. GHG emissions calculated by Delucchi, and reported by Lynd (1996), for ethanol produced from lignocellulose were 16.0 gm/mi of carbon dioxide equivalents, which were only 4 percent of the value calculated for reformulated gasoline.

Lynd believes that "..cellulosic ethanol is one of the leading alternatives for reducing greenhouse gas emissions in the transportation sector". It is significant that Petro-Canada has recently joined forces with Iogen, a Canadian biotechnology company, to investigate the production of ethanol from lignocellulose in Canada (Iogen, 1997).

## 4. ECONOMICS

Synthetic biofuels have to compete with very low priced fossil fuels. Lack of cost competitiveness has been a major problem for fuel ethanol and for biodiesel, the main fuels at present produced from agricultural raw materials. Klass (1998) has calculated that the embedded feedstock cost in ethanol produced from corn grain ranges from 14 to 23 cents (U.S.)/L, depending on ethanol yield, from corn priced at $ U.S. 2.50/bu. The final posted market price (Jan. 1997) was 35.7 cents (U.S.)/L (Klass, 1998). In contrast, methanol (another potential alcohol fuel) produced from natural gas sells for 14.4 cents (U.S.)/L with embedded feedstock costs of 7 to 12 cents (U.S.)/L. Thus the lower cost of natural gas, compared to corn grain, is reflected in the final price of methanol.

Recent prices for gasoline and diesel fuel in Canada (without taxes) have ranged from 18 to 21 cents/L for gasoline and 17 to 20 cents/L for diesel fuel (Energy Analects, Oct 26, 1998). These prices are considerably lower than the U.S. price of 35.7 cents (U.S.)/L quoted above. However, ethanol is sold as an oxygenate additive to gasoline and therefore competes with MTBE (made from fossil fuel sources) as an oxygenate. The current price for MTBE is 17 cents (U.S.)/L, compared to 28 to 29 cents (U.S.)/L for ethanol (Oxy-Fuel News, 1998). But two times as much MTBE as ethanol is required to achieve the same level of oxygen in the fuel; therefore ethanol is competitive with MTBE as an oxygenate for gasoline. The price comparison does indicate that ethanol is considerably more expensive, judged solely as a fuel substitute, than gasoline or diesel.

A related problem would be an increase in the cost of grain. The price of corn has ranged around $ U.S. 2.50/bu. During a brief period in the mid 1990s, corn prices rose to about $ U.S. 5.00/bu as a result of a poor crop in the U.S.A. Some of the fuel ethanol plants closed until corn prices returned to lower levels permitting profitable operations (Klass, 1998).

The ratio of U.S. corn/oil prices (1992 = 100) has declined from a high of 300 to 400/100 in the early 1970s to values closer to 100/100 in the period 1980 to the present (Bluhm et al., 1995). In similar fashion, the ratio of farm crop prices to the industrial commodity price (including textiles, leather, fuels, power, and chemicals) has declined from a high of 180 in 1950 to a low of 90 to 100 in the period 1985 to the present (Bluhm et al., 1995). While this is good news for processors wishing to make industrial products such as ethanol from corn grain, it is not so good news for farmers trying to make a living raising corn.

## 4.1. Biorefineries to increase value of co-products and reduce costs of ethanol

The above comparison does not take into account the value of co-products. It implies that one approach to reducing the cost of ethanol is to obtain higher valued co-products. Several of the ethanol plants in western Canada (Red Deer, Minnedosa and Two Hills, see Table 1) should more properly be called grain biorefineries. Jaycock (1993) calculated the effects of valuable co-products on the price of ethanol as follows:

1. Wheat feedstock @ $100/t and 390 L yield of ethanol. No co-products. Cost of ethanol = 47 cents/L.
2. As in 1 except by-products (30 percent yield from grain, worth $220/t) fed wet to cattle in a feedlot close to the ethanol plant. Value of the co-product = 17 cents/L. Ethanol cost = 30 cents/L. This is the situation at the Lanigan, Sask. plant.
3. As in 1, except 20 percent of feedstock converted to human food at 40 cents/lb with a 20 cents/lb increased production cost; net contribution = 22 cents/L. Some 10 percent of feedstock converted to cattle feed; net to plant = 6 cents/L. Ethanol cost = 19 cents/L. This is likely the situation at the Red Deer and Two Hills plants in Alberta and the Minnedosa plant in Manitoba.

A similar approach is being taken in Quebec, based on biorefining a variety of lignocellulosic raw materials (timothy and reed canary grass, alfalfa, corn stover and barley straw) into industrial feedstocks, animal feed, paper pulp, and ethanol (Jollez et al., 1997). The concept strategy is to produce enough valuable products to enable regional scale plants (40,000 to 60,000 t/yr) to operate profitably, and produce ethanol as a by-product at a price not requiring subsidies.

## 4.2. Reduce the cost of ethanol by advanced methods of production from lignocellulosics.

Lynd (1996) has calculated that ethanol could be produced from poplar wood, using current fermentation technology for converting lignocellulosic feedstuffs to ethanol, for about 31 cents (U.S.)/L, comparable to the cost of production of ethanol from corn grain.The advanced technologies, under development by a number of research groups, might be able to produce ethanol for 13 cents (U.S.)/L, based on large plants using poplar wood (forest residues, crop residues, or possibly switch grass hay) priced at $ U.S. 42.60/tonne, delivered to the plant.

## 4.3. Tax incentives: costs and benefits

Various tax incentives are in effect in Canada and the U.S.A. to support the production of ethanol from grain or other biomass sources. In Canada, the federal excise tax on gasoline, which is 10 cents/L, does not apply to ethanol (Landry, 1997). In Ontario, Alberta, and Manitoba the gasoline taxes of 14.7 cents/L, 9 cents/L and 11.5 cents/L, respectively, do not apply to ethanol. Quebec has also eliminated the gasoline tax on ethanol.

What do governments get to replace their lost revenue? The Government of Quebec calculated the following benefits from the proposed building of the 150 million L/year plant at Varennes: - one thousand jobs during the construction period, - 110 jobs directly at the plant, - 347 indirect jobs with suppliers, - 124 induced jobs arising from the other jobs created, - a new market for local corn production, - reduction in imports of soybean meal, - reduction in imports of carbon dioxide (a carbon dioxide plant is also to be built), - reduction in government farm income stabilization payments. Other food production and food processing plants are being planned to operate in conjunction with the ethanol plant (Landry, 1997). In addition, the Federation des producteurs de cultures commerciales du Quebec are partners with Commercial Alcohols in the ethanol project. They will be investigating methods to make corn production more environmentally sustainable.

Urbanchuk (1996) has calculated the economic effects in the U.S.A. of the federal excise tax removal from ethanol production. Results are shown in Table 3.

Table 3. Economic effects of the ethanol industry in the U.S.A.

| Impacts | | Billions of U.S. $, period 1996 - 2002 |
|---|---|---|
| Final demand | | 50.9 |
| Household income | | 12.5 |
| Direct | 2.1 | |
| Indirect | 10.4 | |
| Additional gov't revenue | | 7.398 |
| Personal income tax | 3.487 | |
| Business income tax | 3.391 | |
| Cost of excise tax | | -3.517 |
| Net gov't revenue benefit | | 3.881 |

### 4.5. Biodiesel from canola or soybean oil: looking for niche markets

Biodiesel is a fuel, or lubricant made by reacting vegetable oils, such as canola or soybean oil, with methanol or ethanol Klass, 1998). The costs of production, when made from rapeseed priced at $ U.S. 220.50/tonne, ranged from 44 to 50 cents (U.S.)/L. This is considerably above the rack price of diesel fuel of about 17 to 20 cents (Can.)/L. Therefore, various niche markets are being sought. For example, low value vegetable oils might be converted into methyl esters, which would be used in diesel engines to improve lubrication qualities of low-sulfur Canadian diesel fuel, reduce engine wear, and improve fuel efficiency (Hertz, 1998). Addition of one percent canola methyl esters improved fuel efficiency by 7.5 percent in a Volvo vehicle (Hertz, 1998). Thus the product would be produced from low quality vegetable oils (to reduce cost) and sold as much as a lubricant as a fuel (to improve product value).

## 5. RECOMMENDATIONS

5.1. Conduct full fuel-cycle analyses of modern Canadian ethanol plants, including scenarios of the effects of changes in agricultural practices to reduce GHG emissions, sequester more carbon in soils, and improve farm income.

5.2. Analyze the benefits to farmers and rural communities of ethanol and biodiesel production, including reductions in transportation costs with the creation of large new local markets to replace distant export markets.

5.3. Conduct Delphi-type discussions of future directions and strategies for biofuels development, including energy companies (e.g., Petro-Canada, Husky, Sunoco), commercial biofuel companies (e.g. Commercial Alcohols), farm organizations, renewable energy organizations, researchers, governments, consultants, and others as appropriate.

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